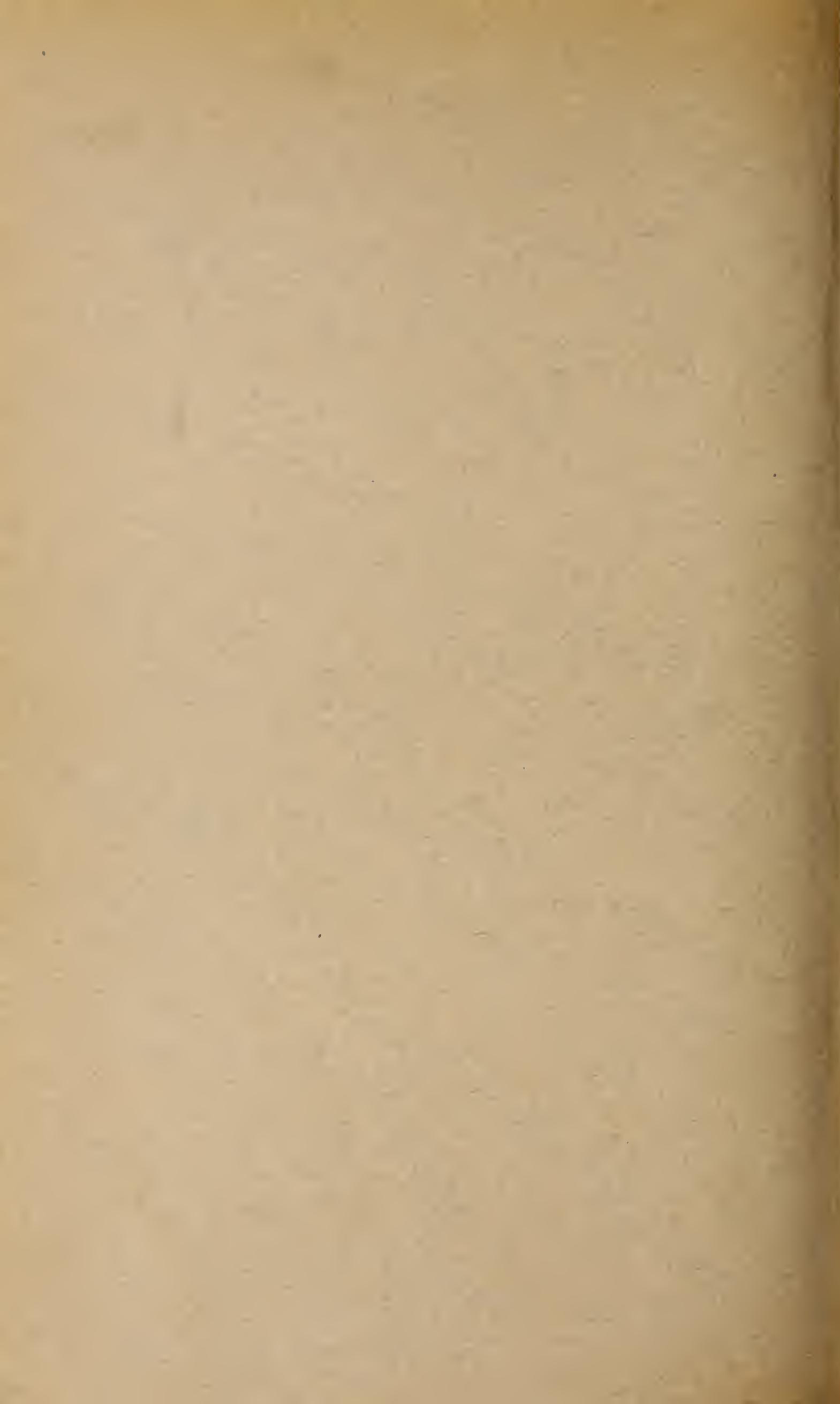


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PORTO RICO AGRICULTURAL EXPERIMENT STATION

MAYAGUEZ, P. R.

Under the supervision of the

UNITED STATES DEPARTMENT OF AGRICULTURE

**REPORT OF THE PORTO RICO
AGRICULTURAL EXPERIMENT
STATION**

1927

Issued January, 1929



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PORTE RICO AGRICULTURAL EXPERIMENT STATION, MAYAGUEZ

[Under the supervision of the Office of Experiment Stations, United States Department of Agriculture]

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CONTENTS

	Page		Page
Report of the director	1	Report of the plant breeder	14
Reforesting	2	Field corn	14
Farm-buildings materials	4	Sweet corn	15
Forage crops	5	Sugar-cane breeding	16
Cattle	6	Report of the agriculturist	19
The banana	7	Pineapple investigations	19
Report of the assistant chemist	8	Report of the plant pathologist	25
Management of cane soils	8	Studies of the genus <i>Phytophthora</i>	25
Report of the horticulturist	11	Citrus root disease	26
Photoperiodism	11	Reports of the parasitologists	27, 28
Coffee	12	General survey	27, 29
Coconuts	13	Liver flukes	31
Mangoes	13	Swine kidney worm	31
Avocados	13	Hookworm of swine	31
<i>Oncoba echinata</i>	13		
Taro, dasheen, and yam	14		

REPORT OF THE DIRECTOR

By D. W. MAY

During the fiscal year covered by this report the weather was generally favorable to crop production. The rainfall was abundant, and there were no severe storms. However, the effect of the hurricane which swept over the island in July, 1926, was apparent in the greatly lessened yield of coffee.

Studies were continued with the pineapple, with especial reference to its composition, habits of growth, fertilizer requirements, and the correlation of plant and soil, to learn, among other things, what compounds tending to inhibit growth are formed by the plant in the soil when rotation is not practiced.

The coffee groves of the island have for some years shown a decreasing production. Yields per tree may be increased by the use of fertilizers. Experiments are being continued to learn what fertilizer combination can be made to give the most profitable yield of coffee.

Studies of nitrogen utilization by cane soils which have been conducted during the last five years were brought to a close. These sought to show the value of leguminous crops in producing nitrogen in lieu of the purchase of this most expensive element in fertilizers.

The substitution of improved methods of propagating carefully selected, vigorous seedlings of known parentage and high-sucrose content for the old method of sowing seed from arrows that have been

selected at random will doubtless contribute toward the progress of the local sugar industry.

Some of the work of the station in plant pathology was done by A. S. Muller, of the College of Agriculture of the University of Porto Rico, in the absence of the regular station plant pathologist, who devoted most of the year to postgraduate work at the University of Missouri. The plant troubles of greatest concern at present include coconut bud rot, citrus scab, and a disease of citrus which apparently attacks the roots of the trees and ultimately causes their death.

The reports of the parasitologists show that a large number of parasites affect the livestock of the island. Notwithstanding an equable climate and an abundance of nutritious grasses during a 12-month growing season every year, there can be no full development of the livestock industry in Porto Rico until the hordes of internal and external parasites which prey upon the animals are brought under control or are exterminated.

REFORESTING

Forest trees make rather slow growth. Every planter of trees is therefore helping in the great work of hastening reforestation. Usually deforested areas have been baked by the sun or leached by the rain, or both, and in consequence are poor in natural fertility. Such areas in Porto Rico are mostly on hillsides that are not adapted to cultivation by machinery. For the smaller areas, fruit-bearing trees, such as the avocado and the orange, may be grown to advantage. Such plantings will enable the grower not only to add materially to his family food supply but also to market the surplus products. For the larger areas mahogany is more promising. Its marketability as a native wood of economic value is certain. Results of experiments at the station during 20 years show that the mahogany will thrive in a great variety of situations. Leguminous nurse crops, preferably trees, should have first consideration in the work of reforesting tropical lands, and can be grown before the main crop is planted, or the two crops may be interplanted to their mutual advantage. Where the trees have been removed from the land the soil usually is deficient in nitrogen, and it is impracticable to purchase nitrogen fertilizers in a scheme of planting for long-deferred returns.

The adaptability of many leguminous trees to certain regions as nurse crops for forest plantings has been demonstrated. The trees include *Acacia* sp.; *Prosopis juliflora*, the pods of which furnish a large amount of palatable feed for stock; *Cassia* sp.; *Gliricidia sepium*; and *Erythrina* sp. Both *G. sepium* and *Erythrina* sp. can be propagated from cuttings and from seed. Some of the leguminous trees can be cut for use as charcoal when their service as nurse crop is no longer needed.

OIL-BEARING TREES

Aleurites moluccana, which was early introduced into Porto Rico, *A. fordii*, or wood-oil trees of China, and *A. trisperma* do well on cut-over areas. *A. trisperma* was introduced by the station from the Philippines and apparently is the most productive of the three species. All three produce hard-drying oils which are suitable for lacquer making, and should be grown on a commercial scale in Porto Rico.

Table 1 gives the constants of the oil of the three species, obtained by different methods of separation.

TABLE 1.—Comparative constants of the oil of three species of *Aleurites*

Determination	Oil of <i>A. fordii</i> ¹	Oil of <i>A. moluccana</i> ²	Oil of <i>A. trisperma</i> (seed) ³	Oil of <i>A. trisperma</i> (whole seed) ³
Average index of refraction	1.5092	1.4785	1.4929	1.4927
Specific gravity	.9410	.9270	.9380	.9383
Acid number	4.0009	2.3000	4.4090	7.1000
Saponification number	192.0000	192.3000	194.0000	190.0000
Iodine number ⁴	(⁴)		(⁴)	(⁴)
Iodine number ⁵	167.8000	162.0000	164.2000	160.5000
Tung oil heat test ⁶	(⁶)	(⁷)	(⁷)	(⁷)

¹ Tung oil or Chinese-wood oil.² Lumbang oil or candlenut oil.³ Soft lumbang oil. "Seed" refers to the kernel alone; "whole seed" refers to the shell and the kernel.⁴ Hanus method. Unsatisfactory.⁵ Hubl method.⁶ Browne method. Firm, crumbly jelly in 10 minutes.⁷ Browne method. Negative.

A manufacturer of tung oil, in a letter to the station, comments as follows on the oil from *A. trisperma*:

Two samples of the oil were received. One was crushed from the seed and one from the whole seed; the former, of course, being lighter in color. Both, however, were of a light amber color, somewhat paler than the commercial grades of lumbang or tung oil obtainable in the market. The odor of each was similar, strongly resembling that of tung oil. In body they also resembled tung oil, being rather viscous.

When the "soft lumbang" oil was spread on glass it dried in 34 hours to an opaque, crystalline film, resembling the film that is produced by raw tung oil. When 10 per cent of lead-manganese drier was added to the "soft lumbang" oil a perfectly clear, firm film was obtained on glass in 14 hours. This result indicated that the oil could be used without heat treatment in the same manner as linseed oil in the manufacture of paints. This result differentiates the oil from tung oil, which is very difficult to use without heat treatment if perfectly clear and hard films are desired.

A small amount of the oil was exposed to the air and sunlight in a partially filled test tube for a period of one week. At the end of that time, an opaque, crinkled mass, light in color, was shown. This mass was removed from the tube. Upon pressure it readily granulated to a meal resembling the meal formed by crushing heat polymerized tung oil. This peculiar physical condition would suggest its use as a filler for inlaid linoleum.

It was found that the granular mass referred to above is of a different nature than the mass formed by heat polymerization of tung oil. Granulated polymerized tung oil is practically insoluble in all solvents and even little affected by boiling caustic soda. The mealy mass from the "soft lumbang" oil was found to be readily soluble in caustic soda (10 per cent solution) with the formation of a clear soap. It was also found somewhat soluble in boiling alcohol.

"Soft lumbang" oil, like true lumbang oil, is not affected by heat as is tung oil, and does not polymerize when brought to 280° C. and held at that temperature for a period of even 15 minutes. During this process, however, the oil becomes viscous (bodied) and apparently is well suited to use in the manufacture of varnishes. Experiments were made in the production of a varnish with "soft lumbang" oil on the same formula used in the manufacture of a tung oil varnish. For this purpose there was used with both oils a percentage of linseed oil and rosin with lead as the drier and mineral spirits as the thinner. Both oils were treated in the same fashion. The tung oil varnish had better body and slightly more rapid drying properties than the "soft lumbang" varnish. Both gave very waterproof films.

Stimulation of the production of "soft lumbang" oil in both the Philippines and Porto Rico should result in available quantities of this oil for use in the United States. Its properties make it most desirable for use in the paint and varnish industry.

FARM-BUILDINGS MATERIALS

Although the solid structures of the North are not required to house livestock in Porto Rico, where the climate is tropical, some kind of building is necessary. Milking sheds are required where dairying is practiced, and stables must be provided to house young stock during their early life and in rainy weather. Farm buildings are uncommon in Porto Rico, the native timbers are scarce, and building material is expensive. The lumber which is now used locally is imported from the States at high cost, and bricks, which were made on the island in the earlier days, are no longer used because of the high cost of the fuel needed in burning.

In seeking for an available material that will prove to be suitable for building purposes, the station carried out a series of experiments with soft limestone, or coral deposit, locally known as "tosca." (Fig. 1.) This material is found in extensive east-and-west deposits



FIG. 1.—House built of soft limestone, or coral deposit, locally known as "tosca"

on both the north and south slopes of the island. These deposits at one time formed the bed of the sea, and on the north side jut out in jagged hills. Exposure to air causes the surface of tosca to harden, but after the crust is broken the material can readily be cut with a spade. Tosca is used as a road-surfacing material, as a ballast for railroad tracks, and as a fertilizer where lime is needed. Table 2 gives the composition of two samples of tosca, one from Aguadilla, on the west coast, and the other from Quebradillas, on the north side.

TABLE 2.—*Composition of two samples of tosca*

	From Aguadilla	From Quebra- dillas
	Per cent	Per cent
Sand and silica (SiO_2)	1.47	5.19
Lime (CaO)	53.76	50.65
Magnesium (MgO)	.87	.77
Ferric oxide (Fe_2O_3)	.56	1.09
Loss on ignition	43.39	41.72

Tosca when mixed in various proportions with cement was found to set quickly and to harden. A mixture as lean as 20 parts tosca to 1 part cement will harden sufficiently for wall building. The proportion of 10 to 1 was found by test to possess two-thirds the hardness of concrete. Tosca is vitreous, does not crack when drying, and therefore does not need to be reinforced with iron. The surface of the combination for use as floors may be further hardened with water glass, or such other chemicals as are used to harden concrete. Tosca mixes easily with cement and can be poured as readily as concrete. The availability and cheapness of tosca should lead to its extended use. It is delivered by railway to the station at \$1.50 per cubic meter.

Adobe, or sun-dried bricks with straw as binder, may be used as a building material in the drier parts of the island, and pisé de terre, or rammed earth, for wall building where the rainfall is more abundant. Rammed-earth construction is durable, can be done by unskilled labor,

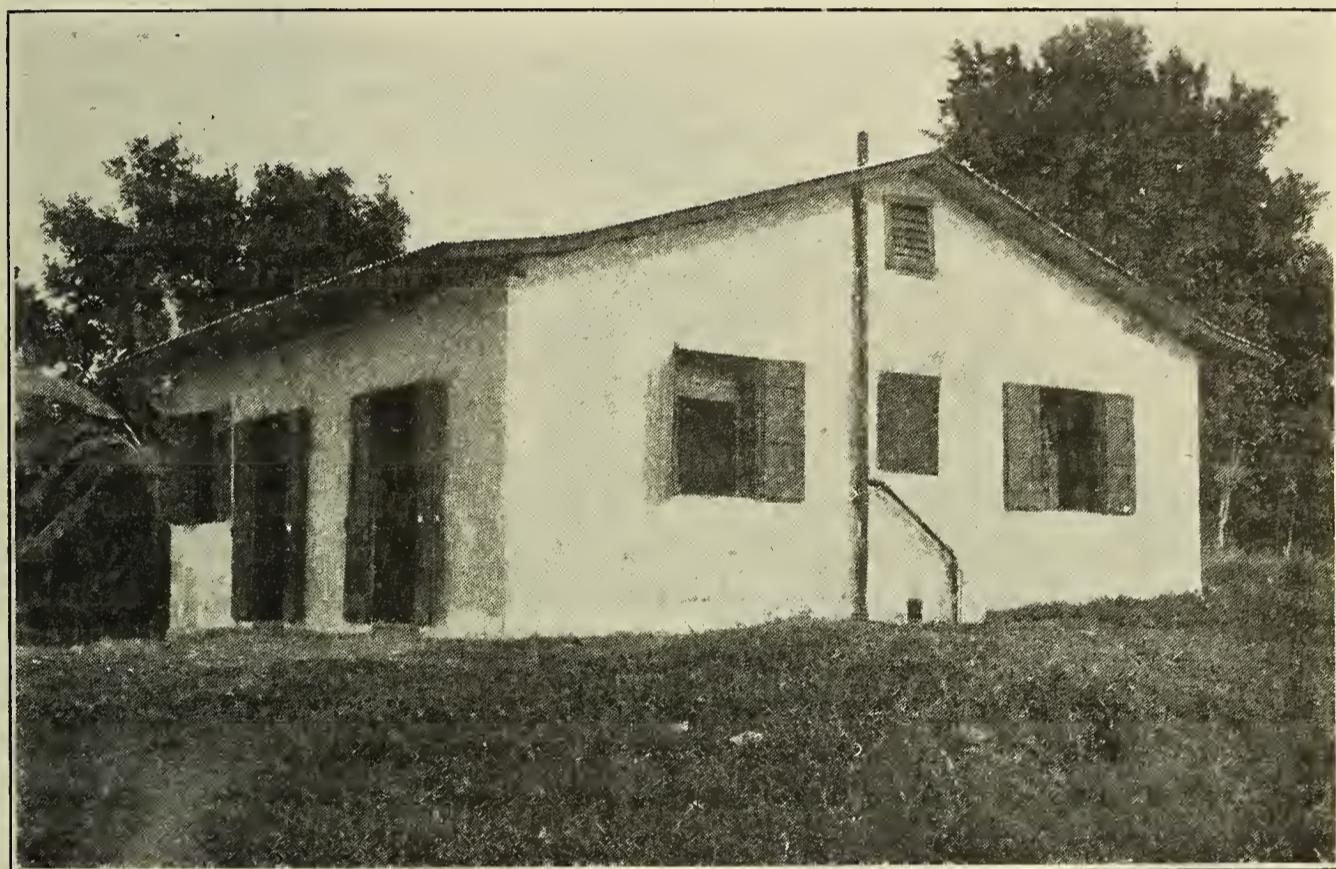


FIG. 2.—House built of pisé de terre or rammed earth

or by the builder in his spare moments, and enables the smallest landowner to erect his own home.

At the station, where the annual rainfall is about 75 inches, the house shown in Figure 2 was built on a concrete foundation and the walls were brushed with tar. The walls were rammed between 2-inch board casings which were well braced to keep them from spreading. The door and window frames were made of 2-inch material and placed when the building was of the proper height. The earth was then rammed at the sides and on top. With a little experience the builder can soon learn what amount of moisture is needed for the most efficient tamping. When the layer is done the earth gives off a ringing sound under the rammer.

FORAGE CROPS

Leguminous plants which produce an abundant supply of palatable and nutritious forage and at the same time increase the nitrogen content of the soil should be given first consideration when feed is to be

grown for livestock. Every grower should learn what legumes will grow successfully in any system of rotation he may practice and whether these same legumes will be relished by the stock on his farm. Legumes should not only be adapted to the soil and climatic conditions in which they are grown, but they should also be able to hold their own successfully, with the minimum cost of cultivation, with tropical rank-growing grasses competing with them. Clovers, for example, should not be grown in regions of heavy rainfall. They are slow in starting and therefore are soon smothered out by grasses and weeds unless given frequent cultivation, which is an unprofitable practice.

The cowpea thrives in Porto Rico and should be more generally grown than it is at present. The vines make excellent stock feed, and the peas, large quantities of which are imported from the States, can be used for human consumption. Some of the vast areas of idle lands throughout the island might well be devoted to the crop.

The soy bean is destined to become one of the important forage and food crops of Porto Rico. Soy beans improve the soil and furnish a larger variety of food products than does almost any other single vegetable. For the successful growing of this crop suitable nitrogen-fixing bacteria are necessary. If they are not already present in the soil, inoculation must be resorted to. Results of experiments at the station show that the soy bean makes its best growth when the seed is inoculated before being planted. The plant grows more rapidly than does the cowpea, matures earlier, and is less likely to be attacked by insect pests.

The velvet bean has been found by the station to be a most valuable forage and green-manure crop for general planting. The plant adapts itself to a wide range of soils in Porto Rico and is of easy cultivation. After the plant starts it will hold its own, climbing over grasses and weeds. Providing the vines with supports promotes seed production. Corn and sunflowers can be used for this purpose. Velvet beans should be planted at the last cultivation of the corn and sunflowers and may also be profitably planted in the stubble remaining after each crop of elephant grass and Guatemala grass is cut.

Uba cane is beginning to be grown for forage in Porto Rico. It ratoons well, tillers profusely, and is a very heavy yielder. A well-balanced green ration may be obtained by interplanting Uba cane with velvet beans at each cutting.

CATTLE

Any excellence characterizing the native cattle is due mainly to the mild, equable climate and the nutritious grasses of the island. The animals are better than might be expected where selection in breeding and concerted efforts to improve them for specific purposes have been neglected. The cattle have been largely employed as draft animals, either in plowing the land or in hauling cane to the mills, and although they have all but been driven from the highways by the autotruck, some are still used in the cane fields. Improvement of the native cattle can best be brought about by crossing them with introduced breeds. Crossbreeding should be directed principally toward improvement in size, vigor, and early maturity for the purpose of increasing strength in the male and quality and quantity of milk in the female.

Within recent years practically every breed of dairy cattle has been brought into Porto Rico. Given good grass and clean water, they have in the main done well. The short-haired breeds have been the least infested with ticks. Very fine progeny, showing improved conformation, early maturity, and increased milk production, have been developed by crossing Milking Shorthorns with the native cattle. Results of experiments in breeding at the station and elsewhere on the island show that of the imported cattle the Milking Shorthorn sire is the best for use where improvement in milk yield, strength, and conformation is sought. The breed is gentle, and even the males may be safely yoked and kept in inclosures having a minimum amount of fencing.

For dairy purposes, the Guernsey seems to be best adapted for improving the native cattle. Guernseys are similar in type to the native cattle, being stocky and strong, transmit their milking qualities to a high degree, and acclimate readily. In milk yields the cross-breds show steady improvement over the native cattle, the average yield of third-generation animals at the station having been increased by more than 70 per cent over their granddams.

That dairying should be developed to supply dairy products, especially milk, for local needs, is shown by the fact that in 1926 the island imported from the States 4,383,371 pounds of powdered and condensed milk, 4,387,896 pounds of cheese, and 593,883 pounds of butter.

THE BANANA

The banana as an important plant of economic value is not fully appreciated by the people of Porto Rico. Plantation owners have never considered the banana as a money crop, and individual laborers on the plantations have grown the fruit largely for the purpose of increasing their food supply. No attempt has been made to solve the market problems of the fruit or to learn how the plant can best be propagated to increase yields. The fruit is in demand on the local markets the year around and should be grown on a commercial scale for profitable shipping to the markets of the mainland.

The banana is of easy culture and is readily propagated from suckers. Shading the ground by the plants reduces cultivation to the minimum. The plant responds to fertilizer and is not easily injured by applications in excess of actual needs. Fertilizers may be applied about the plant, or in small amounts in the axils of the leaves whence they are carried by the rains down the stems to the roots. The banana grows rapidly and for a large plant matures quickly. To make its best development it must receive the proper kind and amount of plant food and be provided with good drainage. Analyses of the banana plant at the station showed that of the three fertilizing elements nitrogen, phosphorus, and potash, potash is found in unusually large percentages. The percentages varied in the different varieties. Gigante (Gros Michel) was found to contain 2.89 per cent potash in the dry matter; Manzano (Apple), 1.8 per cent; Señorita (Lady Finger), 3.7 per cent; Morado (Red), 4.02 per cent; Chamaluco (cooking), 1.83 per cent; and Enano (Cavendishii), 12.17 per cent.

There was a striking relation between the potash content in the above-mentioned varieties and their freedom from disease. Enano, for example, which contained the largest percentage of potash, was

immune to fungus diseases which attacked the other varieties in varying intensities, whereas Chamaluceo, which contained the smallest percentage of potash, was readily attacked by disease and completely wiped out after a short time. Experiments at the station also showed that banana plants which received heavy applications of potash continued to grow from new suckers, whereas plants which were denied this element readily succumbed to disease. Successful culture of the banana would seem therefore to depend upon the growing of vigorous varieties showing a high degree of resistance to disease, the amount and kind of fertilizer given the plant, and good drainage.

REPORT OF THE ASSISTANT CHEMIST

By J. O. CARRERO

MANAGEMENT OF CANE SOILS

Studies on nitrogen utilization by cane soils were brought to a close during the year. A résumé of the work follows:

Until recently no attention was paid to the necessity of returning to the soils the fertilizing elements extracted from it by crops. This fact was impressed upon cane growers and other planters in late years by contrasting the constantly decreasing yields, complete failures during abnormal years, and the necessity of having to replant after two or at most four ratoon crops, with the higher yields and the freedom from necessity of replanting until after harvesting 8 to 10 fine ratoon crops in the same fields in earlier years. It thus became a common practice to increase yields by applying commercial fertilizers, either singly or in combination, to the soil, but little consideration has been given to the possibility of obtaining some of the essential elements from less expensive sources, such as from a better use of the refuse and stubble remaining on the field after harvesting.

Growers of cane in Porto Rico ought to be especially interested in the problem of economic and efficient fertilization, for of the fertilizing elements added to the soil, only lime is prepared on the island. The others are brought in from the outside, thus making their use costly.

In cane fields burning of trash and tops is commonly practiced after the crop is cut, and in places where labor is high burning is done even before the crop is cut. Burning may be labor-saving, but it is wasteful of nitrogen and organic matter, two of the most important soil constituents. From 50 to 70 per cent of the nitrogen which is extracted from the soil by cane crops is found to be in the tops and the trash, and smaller amounts are found in the juice and bagasse. The nitrogen in the bagasse is lost when it is burnt, whereas part of the nitrogen of the juice can be recovered and returned to the soil on clarification of the juice. The largest share of the nitrogen taken up by the crop is lost when the tops and trash are burnt. Experiments at the station were, therefore, planned to learn whether part of this nitrogen could be recovered and in addition the organic matter content of the soil increased by returning the tops and the trash to the soil.

The experiments were made on thirty-six $\frac{1}{40}\frac{1}{3}$ -acre plats where the ground is level and the composition is fairly uniform. The plats were treated with phosphoric acid and potash at the rate of 60 pounds per acre. Half the area was limed and the other half unlimed. In the

first series, 12 plats, 6 limed and 6 unlimed, received no nitrogen. In 4 of these the trash and tops were burnt, and in 2 of the 4 green manure was used. In the other 8 plats the tops and trash were either plowed under or used as a mulch. In 4 of these 8 plats green manure was used every time cane was planted. In the second series of 6 limed and 6 unlimed plats, sodium nitrate was applied to 8 to furnish nitrogen at the rate of 60 pounds per acre, and to the other 4 at the rate of 30 pounds per acre. These 12 plats were treated like the no-nitrogen plats with respect to the trash, tops, and green manure. In the third series, 12 plats received nitrogen at the same rate as the sodium nitrate plats, but in the form of ammonium sulphate, and were treated like the no-nitrogen plats with respect to the trash, tops, and green manure.

Plowing under of tops, trash, and green manure afforded little change for the better for the plant cane crop in the no-nitrogen limed section, but proved to be beneficial in the unlimed section. The first ratoon crop gave a complete reversal of this result, the limed section showing decided gains over both the unlimed section and plats where trash was burnt. In sections where nitrogen was applied either as sodium nitrate or ammonium sulphate no change was observed favorable to plowing under of tops, trash, and green manure. The yields for the limed and unlimed plats were the same, and no noticeable difference was observed between the plats on which the trash was burnt and those on which plowing under or mulching was practiced. The treatment failed to make the yields of the half-nitrogen plats equal the yields of the full-nitrogen plats. However, a comparison of the first ratoon crops showed that the yields from the no-nitrogen limed plats on which the trash and the tops were plowed under or used as mulch nearly equaled the yield from the half-nitrogen plats receiving sodium nitrate or ammonium sulphate, whereas the yield from the unlimed no-nitrogen section was considerably lower. Thus the gain from the employment of trash, tops, and green manure was made by the no-nitrogen crop, especially the limed section.

Analyses of samples of the juice were next made for total solids, sucrose content, and purity to find the effect of the treatments on juice quality. Only 60 per cent of the cane weight as juice was extracted by the mill. Examination showed a tendency toward slightly lower total solids and a more pronounced lowering of the sucrose content for plats receiving ammonium sulphate dressing, though this was not so large where green manure had been used and where half-nitrogen applications had been made. The first ratoons did not do as well as the plant cane. The no-nitrogen plats had the highest total solids and sucrose contents, with the sodium nitrate plats ranking a close second. The juice of cane from these plats was apparently unaffected in quality by the various treatments given the plats.

Samples of juices from plant cane from plats on which the tops and the trash had been plowed under were found to have a higher nitrogen content than samples from plats where burning had been practiced. The juices were apparently unaffected by the presence or absence of lime. The same tendency was observed regarding the phosphoric acid and potash contents, the samples of juice from plats on which trash had been plowed under having the higher percentage. These results were shown by the no-nitrogen and nitrate plats, whereas smaller gains

with the highest mineral content were shown by the ammonia plats. Samples of juices from the first ratoon crop showed loss in mineral content when compared with samples from the plant cane. However, the losses shown by juices from the no-nitrogen plats were smaller than those shown by the nitrate and ammonia plats, so that first ratoon juices from no-nitrogen plats had the highest mineral content, those from ammonia plats ranking a close second, and nitrate plats last.

Trash and tops gave a reversal of the results shown by the juices, for the first ratoon crop had a higher mineral content than the plant-cane crop. Trash and tops from plats on which trash and tops had been either plowed under or used as a mulch had a higher mineral content than did that from plats on which burning had been practiced, but the effect was greater for the no-nitrogen than for the nitrogen-fertilized plats. At the same time, the nitrogen content of the trash and tops from the no-nitrogen mulched plats was higher than from plats where burning had been practiced, and the same was true for the nitrogen-fertilized plats, though these gains were smaller than those shown in the former case. As for nitrogen, the content in the leaves and trash from mulched plats is higher than that from plats where burning was practiced, whether the plats were nitrogen fertilized or not. However, the gains shown by no-nitrogen plats were higher than those shown by the nitrogen-fertilized plats. This extra gain in nitrogen content for the no-nitrogen plats together with their gain in tonnage made the nitrogen recovery of the first ratoon crop decidedly low.

Examination of samples of soil from the different plats at the beginning and again at the close of the experiment showed a slight change toward neutrality in the limed no-nitrogen section, but no change in the unlimed section. The sodium nitrate plats remained the same, whereas of the ammonium sulphate plats the limed section showed a slight gain toward acidity and the unlimed section no pronounced gains. All plats on which the trash and tops had been burned, whether limed or unlimed and with or without applications of nitrogen, showed losses in nitrogen and carbon content. Sections on which the trash had been burned and treated with green manure but given no nitrogen showed gains in carbon, whereas sections receiving also nitrogen showed losses in carbon and nitrogen. Sections on which the trash had been plowed under or used as a mulch showed decided gains in carbon. This was true especially of the no-nitrogen and nitrate plats. The gains shown by the ammonia plats were smaller. The plats with no-nitrogen or sodium nitrate dressings were more or less constant in nitrogen content, whereas those receiving ammonium sulphate showed a loss throughout. This loss was unexpected, for the constant nitrogen content of the no-nitrogen and the sodium-nitrate plats was to be expected, as a decrease or an increase of at least 0.01 per cent in nitrogen content of the soil would have to occur before it can be detected by ordinary analysis and before it can be called remarkable. Such a change means that a gain or a loss of 200 pounds of nitrogen per acre would have had to be made by the plats. The plats under discussion were given only two green manure dressings and some in addition received nothing, others a total of 120 pounds, the rest 60 pounds of nitrogen as sodium nitrate or as ammonium sulphate in two dressings.

From additional side experiments it was learned that the green tops rapidly decompose in the soil and that decomposition is greatly hastened by addition of lime. The dried trash decomposed more slowly than the green tops, but again decomposition was hastened by the addition of lime. Decomposition of the dried trash is slow at first but goes forward so rapidly later as nearly to parallel the rate of the green tops. However, neither green tops nor dried trash showed the rate of decomposition made by the green manure (velvet beans) used in this experiment.

REPORT OF THE HORTICULTURIST

By T. B. McCLELLAND

PHOTOPERIODISM

Studies of the photoperiodism of various economic plants were continued. The shorter light exposure was slightly in excess of 11 hours prior to December, at which time it was reduced by 1 hour. The longer exposure was slightly in excess of 13½ hours until December, when it was extended 1½ hours.

The varieties of onions tested, including White Bermuda, Prizetaker, Yellow Globe Danvers, and Giant White Tripoli, failed to develop bulbs under either of the shorter light exposures. Under both the 13½-hour and the 15-hour daily light exposures the White Bermuda onions quickly formed bulbs and passed into the resting stage. The Prizetaker variety under both the normal and the 13½-hour daily light exposures developed chiefly spring onions, but under the 15-hour exposure formed good bulbs. The Yellow Globe Danvers showed comparatively slight difference in its development under the 11-hour, the normal, and the 13½-hour daily light exposures, remaining in, or developing slightly beyond, the spring-onion stage, but formed good bulbs under a 15-hour exposure. The Giant White Tripoli formed some bulbs under both the normal and the 13½-hour daily light exposures, but showed a more uniformly normal bulb development under the 15-hour exposure. This evidence readily explains the lack of adaptability of certain varieties of onions of the Temperate Zone to tropical conditions.

Little difference in growth in the first nine months was noted for pineapples under the 11 and 13½ hour daily light exposures. Subsequent observations showed that the longer period was the more favorable for vegetative development, blossoming being delayed and much larger fruits forming than under either the normal or the short daily light exposures. The plants were left undisturbed after fruiting for the production of a second crop from suckers. Under the 15-hour daily light exposure many of the older leaves remained turgid and green and continued to function in contrast with leaves of similar age and position, which had either dried or were wilting on the plants receiving the normal and the 10-hour exposures. Blossoming was again much retarded by the longer daily light exposure.

The varieties of white potatoes tested included Red Bliss, Lookout Mountain, and Irish Cobbler. While on the whole the shorter daily light exposure favored tuber formation and the longer exposure favored top growth, the varieties differed considerably in the degree to which they reacted; Red Bliss proving to be the least and Lookout

Mountain the most sensitive. Under a 15-hour daily light exposure Lookout Mountain developed an extraordinary amount of top growth and practically no tubers, whereas under the 10-hour exposure the top growth was much less and tuber formation fair.

Several varieties of corn were grown under both a normal and a 15-hour daily light period, it being impracticable to handle this crop under a shortened light exposure. Porto Rican corn was planted January 26 in a garden plat which was illuminated by 40-watt clear glass electric light bulbs set $6\frac{1}{2}$ feet apart in rows 5 feet apart. The lights were placed at a distance of 3 feet above the soil surface and raised from time to time as growth of the corn warranted. Two months after being planted the corn receiving artificial illumination was taller than the check, but not tasseling, whereas the check was beginning to tassel. The first tassels appeared on the artificially lighted corn 17 days later, when all the normal check plants had finished tasseling and nearly all were silking. Although the artificially lighted plants grew much taller than the check plants the latter were higher in percentage of large, well-filled ears and in total production. For this tropical strain of corn the lengthened daily light exposure favored vegetative development, whereas the shorter light exposures were more conducive to fruiting.

Young coffee plants when kept for seven months under the 10-hour and the 15-hour daily light exposures showed no pronounced difference in growth due to difference in light exposures. The plants produced small, virescent flowers under the shorter light exposure, but developed no normal flowers in either group within the seven months.

COFFEE

The fertilizer tests with coffee were satisfactorily continued, and a bulletin embodying the results of the work to 1925 was issued.¹ Changes were made in the basal formulas used on certain plats at the López plantation at Las Vegas. Results of experiments having demonstrated the superiority of complete fertilizer over nitrogen alone, the plats heretofore receiving the latter were given this year a complete fertilizer high in potash for comparison with plats receiving nitrogen, phosphoric acid, and potash in approximately equal amounts. At present prices of coffee and fertilizer, the latter mixture, which has been applied to the López plats for some years, is producing a handsome profit on the investment in fertilizer. Plats of young coffee for testing the most favorable nitrogen-potash ratio are making fair growth, and a few of the trees are already carrying their first crop.

Scions which were taken from an Arabian tree of notably high yield through a long period of years were grafted on Excelsa seedlings to test the effect of this vigorous stock in increasing the yield of Arabian coffee. To the same end Arabian seedlings were inarched on Excelsa seedlings. Each Arabian individual on its own root will be grown alongside the scion which is being topworked on the Excelsa root. The hurricane which visited Porto Rico in July, 1926, greatly reduced the coffee crop at the station and elsewhere on the island. The coffee trees in some of the plats were injured so severely as to necessitate termination of the work on them. Due presumably to adverse

¹ McCLELLAND, T. B. EXPERIMENTS WITH FERTILIZERS FOR COFFEE IN PORTO RICO. Porto Rico Agr. Expt. Sta. Bul. 31, 34 p., illus. 1926.

weather conditions, the hurricane in July being followed by a severe drought in the winter, the crop is practically a failure in some of the experimental plantings.

Gliricidia sepium has proved to be highly satisfactory in the station plantings as a shade for coffee, and cuttings are being distributed to local planters. The cuttings strike root readily, and growth from both cuttings and seed is rapid.

COCONUTS

The coconut fertilizer work was continued without change. Applications of common salt to coconut trees in the Harvey plantation were begun in May, 1926, but the experiment has not as yet progressed sufficiently to learn the effect on production. For the year ended December, 1926, the treated trees produced on the average 68.5 nuts, whereas the check (untreated) trees led with an average production of 72.9 nuts. At Corsica the plats maintained or improved their yields when potash was included in the fertilizer combination and dropped in production when potash was omitted. The two plats receiving complete fertilizer were higher in yield for the year 1926 than the check and the two plats from which potash was omitted.

MANGOES

The Cambodiana mango is a polyembryonic variety which transmits its characteristics to many of its seedlings. The several seedlings from a number of seeds of the 1919 crop were separated and classified from each seed individually as to size to learn whether initial vigor or size is an indication of hybrid origin. Fourteen of these trees fruited for the first time during the year. Of these, 4 had been ranked as firsts, 4 as seconds, and 6 as thirds in vigor. One which had been ranked as a second showed hybrid origin, and the other 13 conformed to type. The former differed from type in being of smaller size, in having a pinker, thicker, tougher skin, a different aroma and flavor, firmer flesh, and much more abundant fiber. Along with these differences there were points of similarity clearly indicating its derivation from Cambodiana. The larger seedling from the same seed has not yet fruited. The results of the present season show that the largest seedling from a polyembryonic mango may fail to give evidence of hybrid origin, whereas a seedling other than the largest may give such evidence.

AVOCADOS

Additional grafted Guatemalan avocado trees were planted at the station. There are now 24 grafted varieties, mostly Guatemalan, at the station. It is believed that some of these varieties will be of great importance in lengthening the season in which avocados are to be had, which is now limited to a period of approximately five months.

ONCOBA ECHINATA

Twenty-five plants of *Oncoba echinata*, S. P. I. 55465, were sent to the station for trial in May, 1923. They produced their first fruits in a little over three years after being planted and are now fruiting freely. The plants have grown rapidly and vigorously in ordinary heavy red clay soil and apparently are well adapted to local conditions.

TARO, DASHEEN, AND YAM

In plantings of the Penang taro, an increase in the size of cormels used as seed pieces failed to produce a corresponding increase in yield. Cormels weighing from less than 2 ounces to 6 or more ounces were planted in four groups according to weight. The first size gave the heaviest and the second size the lightest yield. On account of its superior table quality and pronounced difference in this respect from any of the taros grown in Porto Rico in the past, the Penang taro is a desirable variety for the home garden. The station is attempting to establish the variety locally as a garden crop. The importation and testing of a new food crop is a simple matter, but its establishment in the gardens of the people is much more difficult. As a means of disseminating the Penang taro in Porto Rico the station placed a man along the roadside to describe the new vegetable to small farmers who were returning to the country. Samples, together with small cormels for planting, were also offered.

The lower-yielding varieties of dasheen, with the exception of Ventura, S. P. I. 47003, have been eliminated from the station plantings. Ventura produces very large handsome tubers, but is a comparatively low yielder, averaging per hill, for the last crop, $3\frac{1}{3}$ pounds of corms and tubers of a size suitable for table use in comparison with approximately 5 pounds from each of the other varieties.

The collection of imported yams at the station has been reduced to a few high-yielding varieties. Of the imported varieties, Sealtop ranked highest in the crop of the year, with an average per hill of 3 pounds 15 ounces, and Purple Ceylon lowest, with an average per hill of 2 pounds 11 ounces. The local varieties gave a much lower average production, Guinea, the standard local yam, ranking highest, with 1 pound 9 ounces per hill, and Mapuey Morado lowest, with 6 ounces per hill.

REPORT OF THE PLANT BREEDER

By R. L. DAVIS

FIELD CORN

No well-established variety of corn which has been introduced into Porto Rico has thus far equaled the native corn in yield. Boone County White, an Indiana corn which grows well in the Philippine Islands, is commercially valueless in Porto Rico; Cuban Yellow, a small flint corn which yields satisfactorily in Hawaii, has failed completely, and Hickory King, a corn from Missouri which is reported to have done well in South Africa, was not worthy of a second year's trial. Thus, corn which is bred in other parts of the world can be relied upon to do well in Hawaii, the Philippines, and in South Africa, but must be developed locally to be successful in Porto Rico.

Crosses were made between a common open-pollinated variety of native corn and 27 lines of corn originating from high-yielding Porto Rican parent ears. These lines had only been self-pollinated twice, but it was thought that the best lines for additional selfing could be determined by comparing the yields of the hybrids with the yields of a common pollinator. Most of the hybrids were expected to equal and a few slightly to exceed in yield the ordinary native corn, which was used as the pollen parent. The results were very encouraging.

The average yield of the 27 hybrids was approximately 20 per cent greater than that of the check variety or pollen parent. Taken as a whole, the ears of the hybrids had very sound grain, and were much freer from mold and from worm injury than the ears of the check. The hybrid plants were sturdy and lodged less frequently than did those of the check variety.

SWEET CORN

While practically all of the vegetables that grow in the Temperate Zone can be and are grown in Porto Rico, no variety of sweet corn has as yet been found to be adapted to island conditions. Northern sweet corn makes very weak growth and usually produces small ears which are so severely attacked by worms as to be scarcely worth harvesting. Green corn is used extensively by the natives but is gathered from the common field corn and is frequently tough and unpalatable.

The station has been fortunate in securing some native sweet-corn seed which has every appearance of desirable quality. It originated from seed which was supplied by the station to S. W. Marvin of Villalba in 1925 and is the result of four seasons' selection work from a sport which was found growing in native field corn. This strain of sweet corn is known as Mayaguez-1. The ears are about 6 inches long and are not severely attacked by worms. The kernels vary in color from light yellow to light pink and are deeply shrunken and elongated like those of the Country Gentleman variety of sweet corn. In early growth the plants are vigorous and similar to those of the native field corn, but at maturity they are somewhat smaller than the latter.

Figure 3 shows typical seedlings of Mayaguez-1 which at 30 days after planting averaged 2 feet in height and were comparatively free from worm injury. Seedlings of Country Gentleman and other sweet-corn varieties from the North at a corresponding age are not so high and invariably are riddled by worms. Figure 4 shows a typical mature

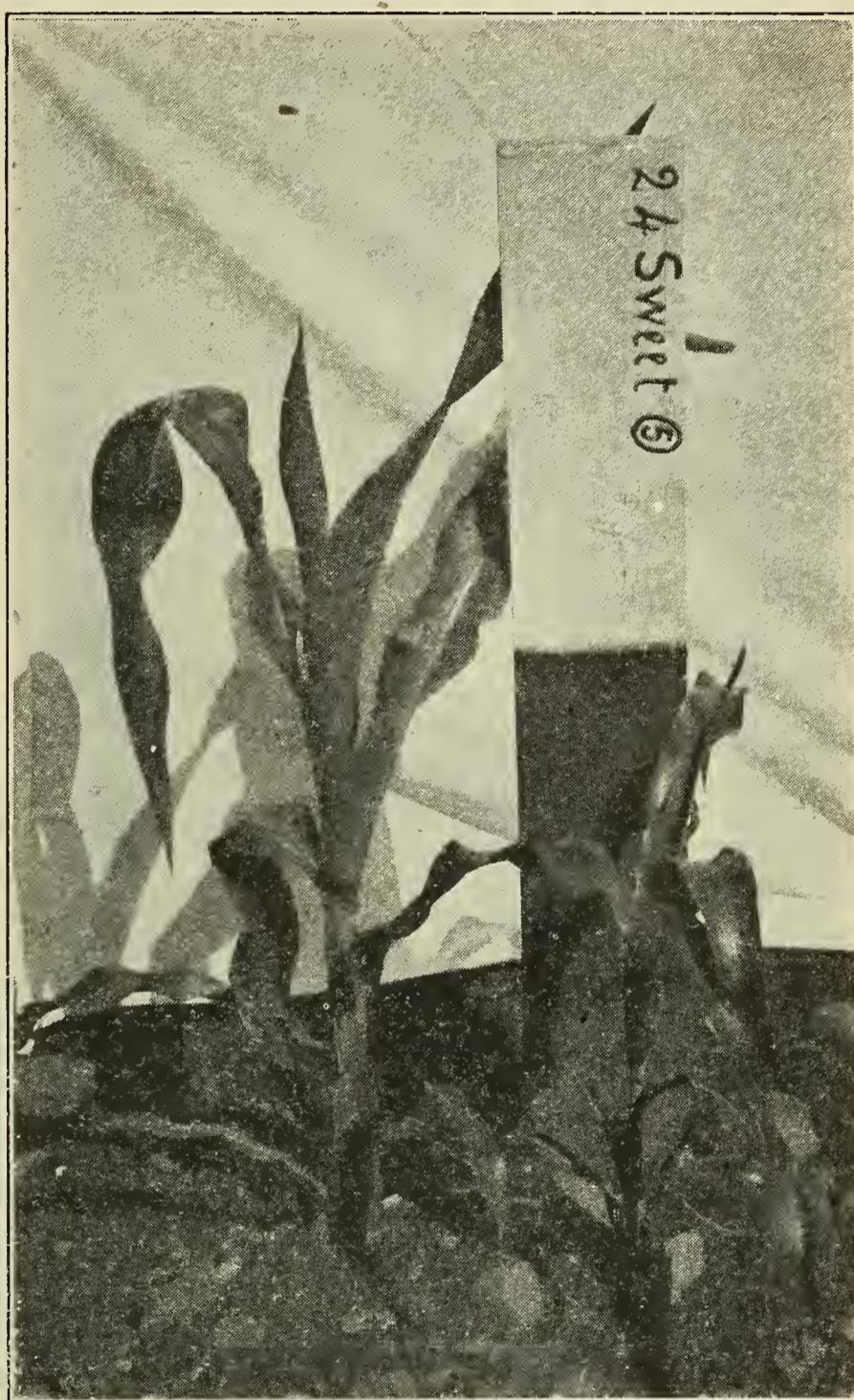


FIG. 3.—Mayaguez-1 sweet-corn seedlings 30 days after the seed was planted. It is 2 feet high and free from worm injury

are deeply shrunken and elongated like those of the Country Gentleman variety of sweet corn. In early growth the plants are vigorous and similar to those of the native field corn, but at maturity they are somewhat smaller than the latter.

plant of Mayaguez-1 which measured 73 inches to the base of the tassel and was without worm injury. Sweet corn from imported seed usually grows 4 feet or less in height. Black Mexican does not average more than 2 or 3 feet tall at Mayaguez. Mayaguez-1 was developed largely from the big sweet-corn ear shown in the upper row left, in Figure 5. This is the third season of selection for kernel type and freedom from worm injury.

SUGAR CANE BREEDING

The goal of the sugar-cane breeder's ambition should be to develop improved varieties which will supplant the old. In Porto Rico and

a number of other cane-growing countries seedlings are commonly propagated from arrows which have been selected at random and no consistent attempt is made to select the paternal parent. The best sugar-producing varieties in the East and the West Indies are, however, all of hybrid origin and indicate the efficiency of controlling both male and female parentage.

During the period 1918-1924, inclusive, some 40,000 seedlings of unknown paternal parentage were propagated at the station and planted in the field. Of this number not one superior variety worthy of commercial testing was developed. In 1925 approximately 5,000 seedlings of S. C. 12/4 were propagated and planted in the field. Of these only one has, during the 1927 season, given a tonnage that justifies additional testing of the hybrid. An examination of the records of hybrids of known parentage, made through the cooperation of the Fajardo Central at Fajardo, Porto Rico, in 1925, showed that P. O. J. 2725 pollinated by S. C. 12/4, 45 were saved for a second year's trial, and of these, 10 at present are worthy of preliminary commercial testing.

of a lot of 350 seedlings of



FIG. 4.—A vigorous typical plant of Mayaguez-1 which measured 73 inches to base of tassel and was free from worm injury

jardo, Porto Rico, in 1925, showed that P. O. J. 2725 pollinated by S. C. 12/4, 45 were saved for a second year's trial, and of these, 10 at present are worthy of preliminary commercial testing.

The results of the first season's efforts at hybridizing at Mayaguez considerably exceeded expectations. A vigorous, drought-resistant hybrid, the result of crossing P. O. J. 2725 and S. C. 12/4 is shown in Figure 6.

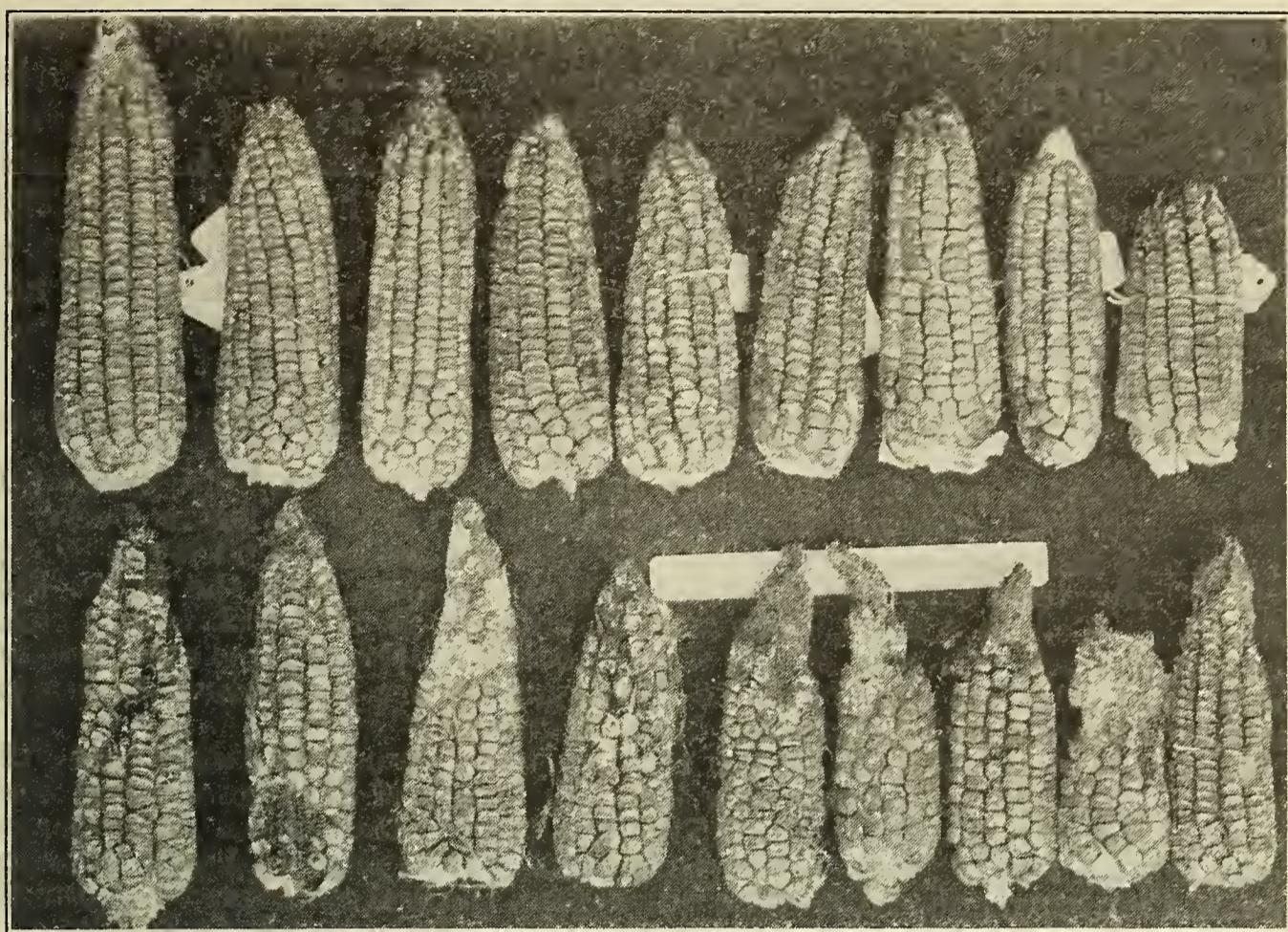


FIG. 5.—Mayaguez-1 was largely developed from the large ear in the upper row, extreme left. Notice its sound grain as compared with that of the lower row ears which were discarded



FIG. 6.—Vigorous, drought-resistant hybrid seedling of P. O. J. 2725×S. C. 12/4. Mayaguez-7 on the right has at 4 months made double the growth of B. H. 10/12 on the left. B. H. 10/12 is suffering from drought, whereas Mayaguez-7 is green and healthy

Mayaguez-7 on the right has at 4 months made double the growth of B. H. 10/12 on the left. The latter suffered somewhat from the drought, whereas Mayaguez-7 remained green and in good condition. P. O. J. 2725 was crossed with S. C. 12/4 in the hope of developing a variety which would prove to be commercially resistant to the mosaic disease and give a tonnage production equal to that of P. O. J. 2725, but lack its early arrowing habit. Only one or two hybrids were expected to show these desirable combinations, whereas seven have resisted all efforts to infect them with the mosaic disease, and have grown as tall as or taller than P. O. J. 2725 and arrowed later.

The following are descriptions of some of the best of the hybrids:

Mayaguez-25 is resistant to mosaic disease, germinates rapidly, grows taller than P. O. J. 2725, yields a cane of good girth, and sheds its leaves freely. In a hand mill test this cane analyzed 17 per cent sucrose and a purity of 87.6 per cent. Under tests which were carried on in cooperation with the South Porto Rico Sugar Co., at Añaseo, Mayaguez-25 outgrew B. H. 10/12, with which it was interplanted. Growth of the first ratoon from the original stool was very good. The principal drawbacks to Mayaguez-25 are its medium-to-low percentage of sucrose and its reclining habit of growth.

Mayaguez-14 is resistant to the mosaic disease, produces larger canes than does Mayaguez-25, and grows very tall. In length of sugar-producing cane it exceeded the growth of P. O. J. 2725 by 3 to 4 feet at Mayaguez. Mayaguez-14 also sheds its leaves freely and stands erect. It is slightly lower in sucrose content than Mayaguez-25, and the ratoon from the first stool was not promising. Mayaguez-14 is somewhat later in arrowing than the parent P. O. J. 2725.

Mayaguez-3 is resistant to the mosaic disease, equals Mayaguez-25 in sucrose content, and exceeds both Mayaguez-25 and Mayaguez-14 in tonnage. Under irrigation at Añasco, Mayaguez-3 was outstandingly superior to B. H. 10/12 in yield of cane. The girth of cane is good and the leaves are shed freely. The cane remains erect and is not attacked by borer. Additional study is needed on the ratooning power of this hybrid before it can be recommended for general planting. Mayaguez-3 has not arrowed during the two seasons it was under test at Mayaguez.

Mayaguez-28 is resistant to the mosaic disease, makes a growth which is not quite equal to that of P. O. J. 2725, but has splendid ratooning power and appears to have a richer juice than either parent. In a hand-mill test this cane analyzed at 11 months (February, 1926) 21.98 per cent sucrose and a purity of 92.7 per cent. The leaves are healthy in appearance like those of P. O. J. 2725 and the hybrid apparently withstands drought equally well. Although Mayaguez-28 arrows early, it produces a rich juice which justifies further testing of the hybrid under varied conditions.

Several other hybrids afford good breeding material, or may be worthy of a trial in short-season regions, such as in Louisiana and in Argentina. Mayaguez-11 gives a good commercial sucrose and closes in so rapidly as to require very little cultivation. The canes are of good girth and tiller well. At 8 to 10 months this hybrid considerably exceeded the growth of B. H. 10/12 under irrigation at Añasco. Mayaguez-11 reached its maximum growth at this time and B. H. 10/12 has since outgrown it. The ratooning power of Mayaguez-11 is not known and the hybrid is not very resistant to the mosaic disease. Mayaguez-5, which produces small canes that exceed P. O. J. 2725 and B. H. 10/12 in growth and resist the mosaic disease, is promising. It is not known whether Mayaguez-5 can compete with Uba, but it ratoons well, has canes of larger girth than the latter, and sheds its leaves freely.

REPORT OF THE AGRICULTURIST

By H. C. HENRICKSEN

PINEAPPLE INVESTIGATIONS

During the past two years an intensive study has been made of the pineapple plant to solve the various problems having a bearing on the industry in Porto Rico. Plants which were functioning normally, as indicated by outward appearances, were compared with plants showing abnormality of some kind. The plant tissues were then carefully studied in order to determine the cause of these differences, and recommendations based on the findings were made to and adopted by some of the planters at once. The investigations thus far have proved to be of immediate value to the local pineapple industry.²

COMPARISON BASED UPON OUTWARD APPEARANCES

LEAF AREA

The leaf area of the Red Spanish variety permits accurately comparing the size of one plant with that of another. A normal plant of desirable strain, which has been grown on suitable soil and under favorable climatic conditions on the coastal plains, has a leaf area approximating 1 square foot for each month of growth, not including the outer withered leaves or the inner small ones. For example, a plant of standard size 8 months old should have 25 to 30 leaves averaging in length 35 to 40 inches and in width $2\frac{1}{4}$ to $2\frac{1}{2}$ inches at a short distance above the base. A plant which falls considerably short in these dimensions when grown under the conditions mentioned may be considered undersized.

SPININESS OF LEAVES

The edges of the leaves of the Red Spanish variety are somewhat spinose and the spines are smaller in number and in size on some of the plants than on others. However, slips from plants having spiny-edged leaves may produce leaves that are nearly smooth edged, and, conversely, slips from plants having smooth-edged leaves may produce leaves that are extremely spiny. These variations have been found to be controlled by varying the food and water supply of the plants. When the supply of both food and water is ample the leaves are usually smooth edged. A shortage of either food or water is likely to result in spine formation as long as the shortage lasts. It is not unusual, therefore, to find plants bearing leaves which are spiny edged in part interspersed with sections that are smooth edged. Some idea of the past growing conditions of the plant can be formed from the spine formation, just as growth periods of a tree can be determined from the rings in the trunk.

²The results have been published for general dissemination in mimeographed numbers of Agricultural Notes, available copies of which may be had upon application to the director of the station.

COLOR OF LEAVES

The color of the leaves is one of the most important factors for detecting abnormality in a plant. The leaves of a normal plant are always dark green, tinged with bronze up to the time the plant blooms. A light green, yellowish, reddish, or nearly white color denotes various stages of abnormality during the growing period. The leaves usually turn rather pale green at the time the plant fruits, but not sufficiently so to make it impossible to distinguish between vigorous and less vigorous plants.

SIZE OF STALK

The plant stalk serves as a reservoir for such plant food as is to be used by the fruit, and must be above a certain size by the time the plant is ready to bloom to produce fruit of normal size. Extensive weight and measurement data show that a stalk $2\frac{1}{2}$ inches in circumference, $7\frac{1}{2}$ inches in length, and one-half kilogram in weight will, under favorable conditions, produce fruit of maximum size, whereas a small stalk weighing, say, 350 grams is likely to fail to do so. On the other hand, an extremely large and heavy stalk may produce a small fruit, which shows that size of stalk is not the only limiting factor in fruit formation.

NUMBER AND SIZE OF ROOTS

The root system of the pineapple plant is governed by the physical condition and chemical composition of the soil in which the plant grows and also by the number and kind of predaceous insects and parasites present. In well-drained and well-aerated soil the roots are usually stout and are sparingly branched but thickly covered with root hairs. A root system which is very different from the kind just described may be considered to be abnormal.

The number of roots present is not an infallible indication of the state of normality. However, corrective measures should be sought when a large plant is practically wanting in roots or when frayed or decayed root stumps are in evidence.

SIZE OF FRUIT AND FRUIT STEM

The size of the fruit is governed by the size of the newly formed bloom and by the development of the fruit after blooming is over. Size of the newly formed bloom depends largely upon size of the plant stalk, and development of the fruit after blooming is over depends upon growing conditions during fruit formation. The Red Spanish pineapple is usually cone shaped, although it may be nearly cylindrical. The eyes are arranged in uniform rows from apex to base. The directions of the rows deviate about 30° from the perpendicular. On the cone-shaped fruit the eyes at the base are larger than those at the apex, and the number of the circumference is 13 regardless of whether the count is made at the apex or base and regardless of the diameter of the fruit. They vary on the line from base to crown as follows: Size 12, 8 and 9 in alternate rows, sizes 16 and 18, 7 and 8 in alternate rows, and sizes 24 and 30, 6 and 7 in alternate rows,

lessening in the same scale with the still smaller sizes. This rule applies very closely for the cone-shaped types, but less so for the short, stubby types.

The diameter of the fruit stem is of considerable practical importance, for a thin stem is likely to break, rendering the fruit unfit for marketing. The thickness of the fruit stem is determined at the time the plant blooms. The portion of the plant stalk developing into fruit stem does not enlarge in diameter by subsequent growth. The planter should therefore grow vigorous plants of a desirable strain in order to avoid loss of fruit on account of weak fruit stems.

SOME CAUSES OF OUTWARD DISCERNIBLE DIFFERENCES IN THE PINEAPPLE PLANT

Such factors as moisture content, reaction of the sap, carbohydrates, proteins, enzymes, and inorganic matter in the leaf must be studied for a determination of the causes of outward discernible differences in the pineapple plant.

WATER CONTENT

Any difference in the water content of the leaves of normal plants and the leaves of abnormal plants depends upon the cause of abnormality. In a normal leaf the approximate water content is 91 per cent in the white-leaf base, 85 per cent in the middle section, and 80 per cent in the section adjoining the apex. When growth is exceptionally vigorous, as in plants the heart of which has been burned out by inorganic salts, the water content of the middle section of the leaf may range from 92 to 94 per cent. These percentages are also common for edemaceous growth, such as is produced when the plant is treated with potassium nitrate. On the other hand, leaves of reddish color and of leathery appearance, due to destruction of some of the roots of the plant, often have a water content of less than 80 per cent. However, a chlorotic condition due to unsuitable soil conditions is not necessarily accompanied by a water shortage in the tissue of the plant. As a general rule, dry tissue is correlated with a high pH of the sap and a high protein-carbohydrate ratio, both of which factors indicate abnormality in the young leaf.

REACTION OF SAP

In the leaves of normal plants the pH of the sap is usually 6 to 6.3 in the middle section, higher toward the apex, and lower toward the base. In young, vigorous growth the pH is practically always lower than in the mature leaves. Likewise, the pH is generally much lower in the leaves of plants of vigorous growth than in the leaves of plants that are somewhat dormant or senescent. For example, a pH of 5 was observed in extremely vigorous growth as compared with a pH of 6.8 in the reddish leathery leaves of a highly senescent plant.

CARBOHYDRATES

The total carbohydrates in the leaves which are hydrolysable by 1 per cent hydrochloric acid, vary according to vigor of growth. For example, the carbohydrate content is about 13 per cent in the young

leaves of very vigorous plants, whereas it is about 30 per cent in red-dish, leathery leaves, and may be as high as 40 per cent in typically chlorotic leaves, all calculated on the dry matter basis.

The distribution of the various sugars also is interesting. The leaves of normal plants contain about 0.5 per cent monosaccharide-hexoses, calculated on the fresh tissue, whereas leaves which are red, leathery, or chlorotic contain over 1 per cent. In the latter case, the leaves contain about three times as much monosaccharide-pentose sugar as the former.

The content of polysaccharides, which are hydrolysable by 1 per cent hydrochloric acid, is higher in the young, vigorous growth than in the more mature leaves, indicating that more of the cellulose is hydrolysable in the immature tissue. Of significance also is the difference in kind of hexoses present. The normal leaves contain a great deal of starch, whereas the chlorotic leaves contain but little. On the other hand, the latter are considerably higher in mucilaginous products than the former, which indicates that starch formation is inhibited in the chlorotic leaf and explains why there is a greater amount of gum formation in the latter case than in the former.

The difference in gum formation is further emphasized by the content of pentosans in the two kinds of tissue. Normal leaves examined contained only 0.36 per cent pentoses, or the corresponding amount of pentosans calculated on the fresh tissue, whereas chlorotic leaves contained over 1.08 per cent.

PROTEINS

The protein content of the leaves of normal and abnormal plants generally varies in inverse proportion to the carbohydrate content. A normal leaf usually contains about 6 per cent protein, calculated on the weight of the dry matter. This percentage may fall to 4 per cent in the leaves of senescent and chlorotic plants, and it may rise to 13 per cent in the young leaves of very vigorous plants. In the latter case the protein-carbohydrate ratio is often as low as 1, whereas in the former case it may be as high as 10 or more.

From the data at hand it appears that as long as the protein content nearly equals the carbohydrate content, the plant will make very vigorous growth. Mature leaves are in about normal condition when the carbohydrate content is three to four times as high as the protein content, but the plant begins to show signs of dormancy or senescence when the carbohydrate content of the leaves is five to six times as high as the protein, and it is either in a very advanced stage of senescence or is very chlorotic when there are 8 to 10 parts carbohydrate to 1 part protein. A high protein-carbohydrate ratio is always correlated with a low chlorophyll, and a high reducing-sugar content is correlated with a high anthocyanin content.

ENZYMES

Peroxidase is present in all parts of the pineapple plant; but the difference in content between an abnormal and a normal plant is small, and the results are not very consistent.

Oxidase is present in such minute quantities as to make its determination difficult and its importance negligible.

Catalase.—The leaves of normal plants contain three to four times as much catalase as do red and chlorotic leaves, and the results of

catalase determinations are consistent, thus offering a possible means of distinguishing normal from abnormal plants.

Reductase.—Nitrates are readily reduced by the leaf tissue of normal plants, whereas there is practically no reducing action by the leaf tissue of chlorotic plants. This fact offers a possible explanation for the difference in nitrate content between normal and chlorotic leaves. In the latter, nitrates are abundantly present throughout, whereas in the former the nitrates disappear at a few inches above the white base.

Diastase.—The diastase content of abnormal leaves does not differ consistently from that of normal leaves. Therefore its determination is valueless in studying the cause of abnormality in the pineapple plant. The diastase content of the leaf increases with its age. Mature leaves usually contain twice as much diastase at the time the plant is fruiting as they did several months earlier. Likewise, young, vigorously growing leaves usually contain only one-third or one-fourth as much diastase as they have several months later.

EFFECT OF FERTILIZER ELEMENTS ON THE PINEAPPLE PLANT

NITROGEN

The color of the leaf and the structure of its tissue are very much affected by the form and the combination of the nitrogen applied to the plant in fertilizers. When ammonium sulphate is used the leaves are normal in color and structure, whereas when either sodium or potassium nitrate is used the plant shows abnormalities. This difference is not due to a preference by the plant for ammonia, for results of pot experiments with sterile sand show that nitrogen is absorbed by the plant in the form of nitric acid rather than in the form of ammonia. However, on field soils where ammonia readily nitrifies and the resulting nitric acid combines with bases, nitrogen in the form of ammonia must be used. Since nitrate-nitrogen is preferred by the plant it would seem reasonable to suppose that the plant would benefit from fertilizer applications containing potassium nitrate, but this is not so. The leaves produced by such plants are edemaceous, shiny green, crooked, and twisted, and the fruit is usually of sugar-loaf shape and of pale color. Frequently no slips are formed, but when present they are few, small, and gnarled.

POTASSIUM

Potassium in considerable quantity is absolutely necessary for normal plant growth. Potassium sulphate is a suitable combination for pineapple fertilizers.

SODIUM

As has been stated, sodium nitrate is not desirable in fertilizers for pineapples. The plants utilize sodium especially when there is a shortage of potassium in the soil, but the physiological effect is not desirable. Sodium produces senescence of the tissue, inhibits normal formation of chlorophyll, and usually prevents the formation of anthocyanin, a pigment which is natural to the Red Spanish variety.

CALCIUM

Like sodium, calcium may be used to replace potassium in fertilizers for pineapple plants, but the effect is undesirable. When the plants are treated with large amounts of calcium salts and small

amounts of potassium salts they will be found to contain these elements in proportion to the application, and the leaves at an early stage of development will become spotted with white and brown.

PHOSPHORUS

The pineapple plant needs very little phosphorus for tissue building. In field experiments plants which were fertilized with ammonium sulphate and potassium sulphate and with very little or no phosphorus invariably were larger, more vigorous, and of better color than plants receiving an additional application of the latter. Similar results were obtained in pot experiments in which the plants were found to contain phosphorus in proportion to the amount applied. Phosphorus is effective in causing early maturity of the leaf tissue. The leaves of plants which are fertilized with generous amounts of phosphate begin to look old much sooner than do the leaves of plants receiving little or no phosphate. That the former actually behave like old leaves is provable by tests for nitrates, catalase, carbohydrates, and proteins.

SULPHUR

Since the various fertilizer elements in combination with sulphuric acid are uniformly suitable for the pineapple plant, and since sulphur is one of the most suitable products for rectifying certain soil defects as well as for controlling nematodes attacking the plant, the question of using sulphur in pineapple growing is of considerable importance. Plants which are fertilized with sulphates contain more sulphur than do plants which are grown without it, but the content of the tissue indicates that the need is amply met when the plant is treated with ammonium sulphate and potassium sulphate. In other words, the element sulphur is not needed when sulphates are used in the fertilizer unless the soil is very alkaline, or the colloidal matter is deflocculated, or nematodes are present in large numbers.

PRACTICAL RESULTS

During the past two years over 100 soil samples were examined at the station and reported upon. As a result of the investigations many of the soils which were found to be unsuitable for pineapples now bear profitable crops.

Sulphur when used in large quantities to check the ravages of nematodes in two fields gave satisfactory results in one and greatly improved conditions in the other. The results indicate the value of sulphur for nematode control in pineapple fields.

Methods of measurement were formulated permitting accurate comparison of the various kinds of abnormality usually found in field-grown plants. Determination of nitrates and catalase in the leaf tissues, for example, reveals some abnormalities that are not perceptible to the unaided eye.

With the knowledge gleaned from the investigations it is possible to answer many questions of practical importance regarding pineapple growing in Porto Rico. Two questions still awaiting answer relate to the control of time of fruiting and of maturing of the fruit and to the potential difference between different plants.

REPORT OF THE PLANT PATHOLOGIST

By C. M. TUCKER

STUDIES OF THE GENUS PHYTOPHTHORA

The plant pathologist was on leave of absence in the United States during most of the year covered by this report. The collection of *Phytophthoras* has been considerably augmented and now contains about 125 strains representing nearly all the principal hosts of this important genus. Studies on the morphology, physiology, and pathogenicity of the strains are being continued. Inoculations of a number of host plants indicate that some species are able to infect a wide range of host plants, whereas others are very restricted in this ability. Observations on the ability of strains to withstand winter conditions in the Temperate Zone show a correlation between oospore production and power to survive winter conditions. Further data will have to be obtained in this regard, however, before definite conclusions can be drawn.

Examinations of oatmeal agar cultures which were kept out of doors during the winter at Columbia, Mo., revealed the presence of oogonia and oospores in two strains of *Phytophthora palmivora*. This is believed to be the first record of the occurrence of sexual spores in pure cultures of the species. Previous workers obtained oospores in mixed cultures only and considered the strains heterothallic.

Continued observations of coconut palms which were inoculated with a strain of *P. palmivora* isolated from *Sabal causiarum* have definitely established its pathogenicity. Inoculations of 10 unwounded coconut palms from 15 to 20 years old resulted in the death of 8 palms showing symptoms typical of bud rot. Parallel inoculations of an equal number of coconut palms with a strain of *P. palmivora* isolated from a diseased coconut palm resulted in the death of 5 palms. The observations were continued 14 months after inoculation.

As a control measure the eradication of coconuts and Sabals infected by bud rot was continued under the supervision of agricultural agents from the insular department of agriculture. A number of new cases appeared during the fall of 1926. The increase was attributed to injuries which were received by the bud tissues during the hurricane of July, 1926, which enabled the fungus to reach the growing point very readily. Normally, the fungus must penetrate several leaf sheaths before reaching the growing point. Cracks in the sheaths in severe storms enable the fungus to penetrate directly.

Bryophyllum pinnatum and the avocado (*Persea gratissima*) are two new hosts of the genus *Phytophthora* in Porto Rico. On the former host the fungus attacks the leaves, causing water-soaked areas which finally blacken and rot. The fungus spreads from the leaves to the stems. The host is not of economic importance, and the fungus is being tested for pathogenicity to other plants.

The avocado *Phytophthora* was isolated from the roots of a young dying tree. The tree had been in an unhealthy condition for several months. The foliage was scanty, small, and of light green color. The leaves were wilting, and most of the roots were black and dead at the time the tree was removed. The blackening was so conspicuous as to suggest association with the chestnut ink disease of France and Italy. In some cases infection had occurred near the tips of the roots and

caused them to die back. In other cases lesions appeared on the bark at any point. The cortical and cambial tissues were destroyed, but the discoloration did not extend deeply into the wood. There was no infection of the crown or of the lower part of the trunk such as accompanies foot rot of citrus and the chestnut ink disease.

Nonseptate mycelium was seen in sections of recently infected tissue, but could not be isolated in culture media because of the presence of a *Fusarium* which outgrew the other organisms. The *Phytophthora* was finally isolated in pure culture by inoculating apples with particles of the infected tissue. The *Phytophthora* produced a decay of the apple tissue much like the decay caused by *P. cactorum* and was readily isolated from it. No inoculations have as yet been made with the organism. One month after the removal of the avocado tree mentioned above, a young avocado tree which was growing at a distance of about 25 feet from it began to show similar symptoms.

CITRUS ROOT DISEASE

A. S. Muller of the local agricultural college was temporarily employed to make a survey of the citrus region along the north coast of the island with special attention to the root disease which has assumed considerable importance at Garrochales, Palo Alto, Manati, and Palo Seco. At Garrochales the branches were dying back, the foliage was scant and of pale green or yellowish color, and there was more or less severe crown rot. Occasional cases of heart rot were observed. In some of the groves the diseased trees had rotted roots. These were brown and firm on the surface and the decay had extended into the wood. In some cases the disease extended as a heart rot from the roots into the crown and the trunk of the trees. Diseased trees were usually found growing in rather close proximity, giving the impression that the trouble was spreading from them to healthy trees. Disease was not found to be associated with certain soil types or with moisture conditions. In one grove the dying trees were more numerous where growth was good than where growth had been checked by a shallow soil. At Palo Alto there was considerable dying back and root decay, but in over half the cases examined the crown remained normal. At Palo Seco numerous trees were observed to be dying in a heavy loam soil. In one grove which is partly marshy, there were no fewer cases of disease in the drier than in the wetter part. Die-back of branches and rotting of roots was observed, but heart rot or gumming at the crown did not always occur.

The disease attacks trees on light, sandy soils, and also on heavy loams. Groves which are comparatively dry throughout the year as well as those on which water stands for considerable periods have lost trees showing the same symptoms—die-back of branches, scant foliage, yellowing, and root decay, with presence or absence of heart or crown rot. Grapefruit trees up to 20 years old have died. In some cases young trees which were used as replants following the removal of dead trees have succumbed. The information at hand concerning the nature of the stocks on which the diseased trees were budded is too meager to permit drawing conclusions as to the relative susceptibility of stocks.

Isolations from dying-back branches yielded in all cases a fungus closely resembling *Colletotrichum gloeosporioides*. Young twigs in incipient stages of dying back were used as sources of material for isolations.

Diseased root tissue was selected at the union of diseased and healthy tissue and when plated in agar produced colonies of *Fusarium* in every case. Bacteria accompanied the fungus in a few instances. Isolations from diseased roots from each part of the region where the disease occurs resulted in cultures of a *Fusarium*, and the strains obtained from the different places are apparently identical. No evidence that the *Fusarium* is pathogenic has been obtained, but further investigations on the question are being carried on.

REPORT OF THE PARASITOLOGIST

By G. DIKMANS³

GENERAL SURVEY

The work in parasitology was begun in 1924. Examination of domestic animals during the period 1924-1926 revealed the presence of nematodes, *Hæmonchus contortus*, *H. similis*, *Ostertagia ostertagi*, *Bunostomum phlebotomum*, *Cooperia* sp., *Æsophagostomum radiatum*, *Trichuris ovis*, *Capillaria* sp., *Syngamus laryngeus*, and *Dictyocaulus* sp., in cattle; *Syngamus laryngeus*, *Hæmonchus contortus*, and *Æsophagostomum columbianum*, in goats; *Crassisoma urosubulatum*, *Hyostrongylus rubidus*, *Æsophagostomum dentatum*, *O. longicaudum*, *Ascaris lumbricoides*, and *Arduenna strongylina*, in pigs; *Tetrameris fissispinus*, *Subulura strongylina*, *Ascaridia lineata*, *Heterakis papillosa*, *Capillaria annulata*, and *Cheilospirura hamulosa*, in chickens; *Heterakis brevispiculum*, *Dispharagus spiralis*, *Ascaridia numidæ*, and *Subulura strongylina*, in guinea hens; *Subulura brumpti*, in turkeys; *Ancylostomum* sp. in the cat; and *A. caninum*, *Ascaridæ* sp., and *Trichuris depressiusculus*, in the dog. Trematodes, *Fasciola hepatica*, were found in cattle; *Posthormostomum commutatum*, in chickens; *Prosthogonimus* sp., in the duck, and *Platynosomum fastosum*, in the cat. *Acanthocephala*, *Macranthorynchus hirudinaceus* were found in pigs, and *Corynosoma* sp. in the cat. Cestodes, *Davainea tetragona*, were found in chickens; *Tænia crassicollis* and *Diphyllobothrium mansoni*, in the cat; and *Dipylidium* sp. and *Tænia marginata*, in the dog.

The external parasites attacking domestic animals in Porto Rico include *Hæmatopinus eurysternus* (Lajas), *Boophilus annulatus* var. *caudatus* (Mayaguez), and *Hæmotobia serrata* (San German) for cattle, *Linognathus* sp. (Mayaguez) and *Boophilus annulatus* var. *caudatus* (Mayaguez) on goats, *Psoroptes communis* in the skin scrapings from a horse (Guayanilla), *Rhipicephalus sanguineus* and fleas on dogs (Mayaguez), and *Echidnophaga gallinacea* on chickens (Guanajibo Mayaguez).

Lice and mites should be effectively controlled wherever dipping vats are available.

Post-mortem examination of a chicken showed one kidney and ureter greatly enlarged. These were submitted to the pathological division of the Porto Rican School of Tropical Medicine, the director of which called the attention of the parasitologist to the presence of trematode eggs in sections of the kidney. The trematode was not found.

It is of interest to note the finding of *Syngamus laryngeus* in the goat. The nematode has been reported in cattle in Porto Rico,

Bagné (1921), but so far as it is known this is the first record of finding the parasite in goats, unless *Syngamus nasicola* Von Linst (1899) is considered to be identical with *S. laryngeus* Raillet (1899). Chapin in 1925 showed that these species are very probably identical. *Æsophagostomum longicaudum* was found in pigs in New Guinea by Goodey of the London School of Tropical Medicine. The parasite apparently is widely distributed over the world. *Subulura strongylina* has been found in chickens and various other kinds of birds in Brazil but has not been previously reported as a parasite of guinea fowls. *Heterakis brevispiculum* is apparently frequently present in guinea fowls in Dahomey and Belgian Congo, Africa, and more recently has been reported from Brazil. *Ascaridia numidæ* is known as a parasite of guinea fowls in Africa. *Heterakis brevispiculum* and *Ascaridia numidæ* in the guinea fowl and *Subulura strongylina* in chickens and the guinea fowl have not previously been reported from the United States. However, since comparatively few domestic fowls were examined, the data obtained are insufficient to permit drawing general conclusions. In general the parasites attacking cattle in Porto Rico are similar to those molesting these animals in the continental United States. A survey of the distribution and prevalence of animal parasites in Porto Rico should be of decided interest. With the exception of the rather frequent finding of *Crassisoma urosubulatum*, the internal parasites of pigs in Porto Rico presented no novel features. *C. urosubulatum*, however, in view of its relationship to the general group of Ankylostomidæ may prove to be of paramount importance. Studies of the prevalence and distribution of the parasite should be made.

The fluke *Posthormostomum commutatum* has been reported as a parasite of the chicken, turkey, guinea fowl, and pigeon in Italy and Tunis, but is reported here for the first time from the United States. *Platynosomum fastosum* of the cat appears to be common in Brazil, but is reported here for the first time from the United States.

The parasitologist gratefully acknowledges his indebtedness to the experts of the Division of Zoology, Bureau of Animal Industry, United States Department of Agriculture, for their courtesy in identifying many of the parasites mentioned in his report.

REPORT OF THE PARASITOLOGIST, 1927

By H. L. VAN VOLKENBERG

The parasites collected during 1927 which were heretofore unreported for Porto Rico are as follows: Of the internal parasites, the nematodes are *Filaria labiato-papillosa*, from abdominal cavity, and *Onchocerca* sp., from ligamentum nuchæ, in cattle; *Synthetocaulus capillaris*, *Trichuris ovis*, *Chabertia ovina*, and *Æsophagostomum venulosum*, in goats; and *Metastrongylus elongatus*, *M. brevivaginatus*, *Stephanurus dentatus*, *Trichuris suis*, and *Necator suillus*, in swine; Protozoa, *Eimeria zurni*, in cattle; trematodes, *Paramphistomum cervi*, in cattle; *Fasciola hepatica*, in goats and swine; cestodes, *Moniezia alba*, in cattle; *Tænia* sp. and *Cysticercus tenuicollis*, in goats; *C. cellulosæ* and *C. tenuicollis*, in swine; and of the external parasites, *Ornithodores meginini*, *Demodex folliculorum*, and *Hypoderma* sp., in cattle; *O. meginini* and *Trichodectes* sp., in goats; *Dermacentor nitens* and *Dermatophilus penetrans*, in swine; *D. nitens* and *Trombicula* sp., in horses; and *Gonioco-*

tes gigas, *Menopon pallidum*, *Lipeurus* sp., *Cnemidocoptes mutans*, *Dermanyssus gallinæ*, and *Trombicula* sp., in chickens.

The leading projects under investigation include (1) a general survey of the parasites affecting domestic animals in Porto Rico; (2) a study of the liver fluke and its relation to disease in cattle, goats, and swine; (3) a study of the life history and economic importance of *Stephanurus dentatus*; and (4) the possible relation of *Necator suillus* to the problem of human ankylostomiasis in Porto Rico.

GENERAL SURVEY

The first project has received the most attention. The bulk of the material has been obtained from the local abattoir. Approximately 100 sets of viscera of cattle, goats, and hogs have been systematically examined to determine the species of parasites, the percentage infested, and the importance of the parasites collected. In addition, data have been recorded for publication later, of the examination of fecal material, skin scrapings, etc., of animals in this vicinity and at distant points on the island.

The studies made so far indicate that the most serious parasites attacking cattle, arranged tentatively according to their economic importance, are stomach worms, Texas fever ticks, liver flukes, nodular worms, lung worms, mange mites, coccidia, flies, and lice.

The seriousness of stomach worms and also nodular worms has forced cattle raisers in certain localities to keep their animals in board-floored pens elevated above the ground, occasionally cement-floored pens, and to feed them by hand until they were several months old. Even so, fecal examination of these calves which had never been on pasture has shown that many are infected and some heavily, demonstrating that these parasites can be picked up in pens, which are theoretically regarded as being parasite proof. Apparently infective larvæ have been carried to the pens on grasses cut from fields which had been fertilized with stable manure, and a heavy reinfection may have occurred as a result of insanitary conditions in the pens. However, healthy calves are being successfully raised by several dairymen in the heavily infested districts by keeping the animals off pasture until they become 8 to 12 months old and dosing regularly, once each month, with a solution of copper sulphate.

An unidentified filarial worm, attached to the cervical ligament, has been found in over 80 per cent of the cattle examined. The parasite apparently is of no pathogenic importance.

Of the external parasites, the cattle tick is widely distributed and carries tick fever as elsewhere. The spinose ear tick has been collected from several cattle. A large sucking louse is common and is found, together with the eggs or nits, in the switch of the tail and occasionally, especially in a heavily infested animal, among the long hairs on the inner edge of the ears.

The mange mite, *Demodex folliculorum*, has been identified from the scrapings taken from a cow near San Juan and a calf at Mayaguez. Larvæ of an ox warble fly were seen on three cows which were recently imported from the States.

Evidently conditions are unfavorable to the fly, as the larvæ are often imported on cattle and reinestation is not known to occur.

Very few data have been obtained on the losses in swine due to parasitic infestation. However, parasites probably partly account for the many stunted and emaciated animals which have been frequently observed.

Dikmans, in a former report of the station,⁴ gives the results of a systematic examination of the small intestines of 60 pigs. Of internal parasites, lungworms were found in over 50 per cent and lardworms in over 40 per cent of the animals. *Cysticercus cellulosæ*, the larval stage of *Tania solium*, a dangerous tapeworm in man, was found in two hogs slaughtered at the abattoir. Both animals were heavily infested.

Of the ectoparasites, the sand flea, locally known as "nigua," is common in pigs which are raised near the seashore. The flea burrows into the skin above and between the claws and sometimes causes considerable inflammation. The tropical horse tick was found in the ears of two pigs.

Very little is known regarding the seriousness of parasites affecting goats. Stomach worms were found in about 75 per cent of the goats examined. Apparently the adult native goat is less resistant to stomach worm infestation than are cattle, and the kid is more resistant to the resultant bad effects from infection than are calves. The goat should be considered as an important factor in the dissemination of stomach worms, as the same species occurs in both goats and cattle.

Nodular worms were found in over 70 per cent and whipworms in about 30 per cent of the goats examined. Lungworms and liver flukes were common. *Syngamus laryngeus* is much more common in goats than in cattle and the number of parasites per animal is usually much greater in the goat. A few specimens of *Chabertia ovina* were recovered from a goat which had been recently imported from the States.

Of the two species of lice which had been found on goats, the biting louse is the more common. The goat as a carrier of cattle ticks must be taken into account if eradication of this parasite is attempted. Spinoce ear ticks were found on several goats.

Some study has been made of the external parasites of horses. Psoroptic mange has been found in three widely separated localities. One of these findings was made by Dikmans. This and reports by laymen indicate that this form of mange is widely distributed. The tropical horse tick was collected from several horses at Mayaguez. The larvæ of a trombidium mite has been found attacking the face and head and occasionally the body. This mite is very common in this vicinity, especially during the wet season. The irritation caused by it is very great, especially in thin-skinned horses. Affected animals have a characteristic appearance in which hair in numerous small spots is lost from rubbing, but the crusts, scales, and thickening of the skin, distinctive of some manges, are absent.

The dermatitis of both horses and cattle caused by mites, lice, and bacteria will require considerable study, as these forms of skin diseases are common and serious in Porto Rico and very little is known concerning them.

⁴ Dikmans, G. REPORT OF THE PARASITOLOGIST Porto Rico Agr. Expt. Sta. Rpt. 1925: 22, 1927.

LIVER FLUKES

The study of the liver fluke is not completed. Several species of fresh-water snails were collected and examined for the purpose of finding the intermediate host. An endeavor is being made to carry out part of the life cycle of the parasite in the laboratory. Uninfected snails are being infected with the miracidia from the eggs of the liver fluke, and the cercariæ thus produced in the snail will be in turn transmitted to experimental animals. The cercariæ from snails taken in the field are also being transmitted to animals. A study will be made with the view of controlling this parasite either by medicinal treatment of infected animals or by destroying the snail in the field, or both.

SWINE KIDNEY WORM

The study of the life history of the kidney worm, *Stephanurus dentatus*, of swine has indicated that infection is direct and that the larvæ undergo a stage of development in the liver of the pig before passing to the fat surrounding the liver and kidneys.

HOOKWORM OF SWINE

The study of the hookworm, *Necator suillus*, of swine has been handicapped by the lack of material. A systematic examination of intestines from over 100 pigs disclosed a light infestation in only 2 instances. This indicates that the parasite is not common, at least in the vicinity of Mayaguez.

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